INSTRUCTION MANUAL

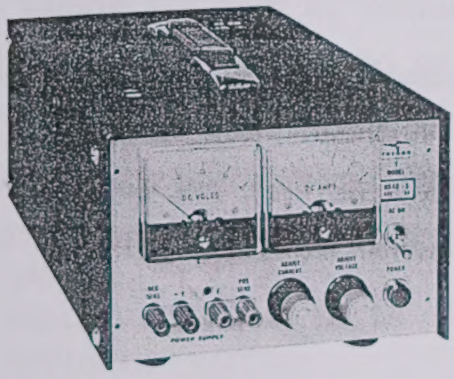
TRYGON ELECTRONICS

MODEL HR60-2.5A

23192E

MEDIUM POWER HALF RACK

TRANSISTORIZED POWER SUPPLY



TRYGON ELECTRONICS, INC.
111 Pleasant Avenue
Roosevelt, L. I., New York
(516) FReeport 8-2800
TWX No. 516-868-7508

IMPORTANT NOTICE

MEASUREMENT OF REGULATION AND RIPPLE

THE SPECIFICATIONS CITED HEREIN FOR REGULATION AND RIPPLE CAN BE READILY ATTAINED ON EVERY TRYGON POWER SUPPLY, PROVIDED THE PROPER METHOD OF MEASUREMENT IS EMPLOYED.

(REFER TO FIGURE 2-3 ENCLOSED FOR THE DETAILED TEST SET-UP)

THE MAJOR CONSIDERATION IS THAT THE HIGHLY STABLE METER AND OSCILLOSCOPE MUST BE CONNECTED TO THE SENSING TERMINALS AND NOT AT THE LOAD TERMINALS. THE REASON FOR THIS PRECAUTION IS THAT THE VOLTAGE DROP BETWEEN THE LOAD TERMINALS AND SENSING TERMINALS WILL YIELD AN INACCURATE REGULATION AND RIPPLE MEASUREMENT.

TABLE OF CONTENTS

SECTION I - DESCRIPTION

PARAGRAPH	TITLE	PAGE
1.1	GENERAL	1-1
1.2	GENERAL FEATURES	1-1
1.3	PRECAUTIONARY MEASURES	1-3
1.4	ELECTRICAL SPECIFICATIONS	1-4
1.5	PHYSICAL SPECIFICATIONS	1-5

SECTION II - INSTALLATION AND OPERATION

PARAGRAPH	TITLE	PAGE
2.1	MECHANICAL INSTALLATION	2-1
2.2	ELECTRICAL CONNECTIONS	2-2
2.3	CONTROLS	2-3
2.4	SUPPLEMENTARY CONTROLS	2-4
2.5	OPERATION	2-5
2.6	OPERATIONAL TEST PROCEDURE	2-7

SECTION III - THEORY OF OPERATION

PARAGRAPH	TITLE	PAGE
3.1	GENERAL	3-1
3.2	BLOCK DIAGRAM ANALYSIS	3-1
3.3	OPTIONAL FEATURES	3-7

SECTION IV - MAINTENANCE

PARAGRAPH	TITLE	PAGE
4.1	GENERAL	4-1
4.2	TEST EQUIPMENT REQUIRED	4-1
4.3	TROUBLESHOOTING	4-1

TABLE OF CONTENTS

SECTION V - CALIBRATION

PARAGRAPH	TITLE	PAGE
5.1	GENERAL	5-1
5.2	TEST EQUIPMENT REQUIRED	5-1
5.3	CALIBRATION PROCEDURE	5-1

LIST OF TABLES

TABLE	TITLE	PAGE
2-1	FRONT PANEL CONTROLS	2-3
2-2	INTERNAL CONTROLS	2-3
2-3	SHORTING LINK APPLICATION, REAR PANEL	2-4
2-4	SHORTING LINK APPLICATION, FRONT PANEL	2-5
4-1	RELATIVE RESISTANCE VALUES	4-2
4-2	ZENER DIODE VALUES	4-3
4-3	TRANSISTOR BIAS AND SATURATION VOLTAGES	4-8

APPENDICES

ELECTRICAL PARTS LIST
PHOTOGRAPH
COMPONENT BOARD LAYOUT
BLOCK DIAGRAM
SCHEMATIC DIAGRAM

SECTION I-DESCRIPTION

1.1 GENERAL

The Medium Power Half Rack Series power supply has been designed to provide a flexible and dependable source of D.C. power to meet a variety of needs. These needs may range in scope from inspection and production testing, to laboratory bench testing and systems applications.

The wide range of outputs available makes this unit well suited for use as a basic laboratory power source. The ability to provide power packaged in minimum space with high reliability, meets the demands of most systems requirements.

All components used in the construction of the Medium Power Half Rack units are of the highest quality available, and have been subjected to 100% incoming inspection.

Each electrolytic filter capacitor is of computer grade, and has been quoted by the manufacturer as having a life expectancy exceeding ten (10) years. Each power transistor has been "derated" and temperature aged to provide high reliability. All rectifiers are hermetically sealed silicon units, and all Zener diodes have been temperature stabilized.

1.2 GENERAL FEATURES

Output, Sensing, Remote Voltage Programming and Remote Current Programming terminals are located on a terminal board mounted on the rear panel of the unit. The power switch, pilot lamp, current and voltage controls and appropriate metering devices are all located on the front panel. For convenience, additional terminals for output and sensing have been provided on the front panel.

1.2.1 Constant Voltage Mode

A constant voltage is maintained across the output terminals at any pre-set value from zero to rated voltage output, provided that the load does not draw more than either the rated output current or more than the pre-set limiting current value determined by the front panel current control settings.

1.2.2 Constant Current Mode

Constant Current operation is achieved by maintaining a constant voltage across an internal current sensing resistor. An automatic cross over network changes the mode of operation from Constant Voltage to Constant Current when the current demand exceeds that of the pre-set current adjust control. The point at which the operating mode automatically changes is a function of variations in load conditions. The cross over point is adjustable, and can be established anywhere within the current and voltage range of the unit.

1.2.3 Automatic Current Limiting

Short circuit protection is provided by the Automatic Current Limiting circuit which limits the maximum output current under all load conditions. The point at which automatic current limiting occurs is variable, and may be selected anywhere from 25ma to the rated output of the unit. In the event of a short circuit, the output voltage drops to zero, and returns to normal only when the short circuit is removed.

1.2.4 Automatic Overvoltage Protection (Optional Feature)

Automatic Overvoltage (OV) protection is available as an option. Special circuitry automatically tracks the programmed output voltage and prevents it from exceeding a pre-set value. This occurs in the event of an internal component failure or external over voltage.

1.2.5 Remote Programming

Remote Programming is provided in both the voltage and

1.2.5 Remote Programming (Continued)

current modes of operation. Both voltage and current may be remotely programmed over their entire ranges. The scale factor for Remote Voltage Programming is 100 ohms per volt. The Remote Current Programming is approximately determined by computing the value of the programming resistor using the formula

$$R_{PGM} = 100 \left(1 - \frac{\text{Load Current}}{\text{Rated Current}}\right)$$

1.3 PRECAUTIONARY MEASURES

1.3.1 Wire Size

To assure proper regulation under all load conditions, and to prevent severe distortions of the AC line voltage, it is very important to take into consideration the physical size and current handling capabilities of the input power line. The maximum AC impedance from the breaker box to the power supply input must not exceed 3/4 ohms.

1.3.2 Voltage Regulator and Inverter Inputs

Do not use voltage regulators or inverters as a primary power source. The outputs of these devices are usually not sinusoidal in nature, and if used as the AC source for the power supply, will cause serious loss of regulation of the power supply output. Capacitive input filtering used for semiconductor power supplies requires charging to the peak of the rectified AC wave which non sinusoidal AC sources cannot provide.

1.3.3 Variable Transformer Input

If a variable transformer is to be used to test the power supply for low and high AC line operation, it must be able to supply at least twice the VA requirements of the power supply and load.

1.3.4 Systems Considerations

In systems applications it is recommended that each power supply input power line be run separately to the AC distribution

1.3.4 Systems Considerations (Continued)

box, in order to minimize cross coupling and interaction between equipment. Do not run sensitive signal leads such as the remote sensing leads in the same cable as the AC input without shielding. It is strongly recommended that the AC input cables should not be run in close proximity to the output load cable leads, if minimum ripple is desired.

1.3.5 Terminal Post Resistance

All terminals and shorting links serving Outputs, Sensing and Programming must be securely tightened before use. Serious loss of regulation and an increase in ripple can result due to a voltage drop caused by loose terminals and shorting links.

1.4 ELECTRICAL SPECIFICATIONS

1.4.1 General

A) Input - 105 to 125 VAC, 55 to 65 cps
B) Output - 0 to 60 VDC, 25 ma to 2.5A
C) Ripple - Less than 0.5 mv RMS
D) Line Regulation - 0.01% or 2 mv (whichever is greater)
E) Load Regulation - 0.01% or 3 mv (whichever is greater)
F) Nominal Impedance - 0.008 ohms from DC to 1000 cps

1.4.2 Constant Voltage with Adjustable Current Limiting

A) Voltage Output - 0 to 60 VDC
B) Line Regulation - 0.01% or 2mv (whichever is greater), for 105 to 125 VAC line change at any output within specifications.
C) Load Regulation - 0.01% or 3mv (whichever is greater), from no-load to full-load condition at any output within specifications.
D) Ripple - Less than 0.5mv RMS.
E) Stability - 0.05% or 18mv (whichever is greater), for 8 hours after initial warm up.
F) Ambient Operating Temperature - -20°C to +50°C

1.4.2 Constant Voltage with Adjustable Current Limiting (Cont.)

G) Temperature Coefficient - 0.02% per °C

H) Recovery Time - Less than 50 USEC to recover within 10mv of output for 100% step change in rated current.

J) Short Circuit Protection - Automatic Current Limiting (ACL), variable from 25ma to rated current.

K) Remote Programming - Fully programmable over the full voltage range at 100 ohms per volt.

L) Remote Sensing - Front and rear panel terminal connections provide for rated regulation directly at load.

1.4.3 Constant Current with Adjustable Voltage Limiting

A) Current Output - 25ma to rated current output

B) Voltage Compliance - 0 to rated output voltage

C) Regulation - 0.5% or 10ma (whichever is greater), no load to full load at any output within specifications.

D) Ripple - 0.25% or 5ma (whichever is greater)

E) Stability - 0.5% or 10ma (whichever is greater), for 8 hours after initial warm-up.

F) Temperature Coefficient - 5ma per degree Centigrade

G) Remote Programming - Fully programmable over complete current range.

1.5 PHYSICAL SPECIFICATIONS

1.5.1 Controls, Front Panel

A) Voltage - Course and Fine; 0 to rated output

B) Current - Course and Fine; 25ma to rated output

C) Power - Two position switch and indicator

1.5.2 Metering, Front Panel

A) Voltage - Voltmeter 0-60V

B) Current - Ammeter 0-2.5A

1.5.3 Terminals, Front Panel

A) Positive Sensing
B) Positive Output
C) Negative Output
D) Negative Sensing
E) Ground

1.5.4 Terminals, Rear Panel

A) Positive Output (7)
B) Negative Output (1)
C) Negative Sensing (2)
D) Positive Sensing (6)
E) Ground (11)
F) Voltage Programming (3) (4) (5)
G) Current Programming (8) (9) (10)

1.5.5 Dimensions

A) Width - 7 3/4 inches
B) Height - 4 7/8 inches
C) Depth - 14 inches
D) Weight - 23 pounds

SECTION II - INSTALLATION AND OPERATION

2.1 MECHANICAL INSTALLATION

2.1.1 General

If the Medium Power Half Rack series power supply is to be used in a portable bench type configuration, no special mechanical installation is required. However, if the unit is to be rack mounted, special rack mounting adapters must be used to secure the unit to the relay racks. Single (RPA-1) and dual (RPA-2) rack panel adapters are available.

2.1.2 Rack Panel Adapter Mounting

1) Remove the 6-32 screws which fasten the cover to the power supply chassis.
2) Remove and rotate the cover so that the front is now facing to the rear, and the screw holes line up with the tapped holes in the chassis.
3) Observe and mark the location of the terminal posts of capacitors C8 and C9.
4) Remove the two phenolic insulating strips from their old locations and re-fasten them to the new locations determined in the previous step. (Not required on later models)
5) Fasten the cover securely in position with the 6-32 screws previously removed.
6) Attach the handles to the Rack Panel Adapter.
7) Stand the Rack Panel Adapter in front of the power supply. In order to mount the power supply properly, the top of the Rack Panel Adapter must face up. The top is distinguishable from the bottom in that all the holes, including those for the handles, are in a straight row across the front of the Rack Panel Adapter.

2.1.2 Rack Panel Adapter Mounting (Continued)

8) Attach the power supply to the Rack Panel Adapter with the 6-32 screws and lock washers provided.

2.2 ELECTRICAL CONNECTIONS

2.2.1 Input, Power:

A heavy duty 3 wire line cord and molded plug with grounding prong provides a path for input power to the unit.

2.2.2 Output, Rear Panel:

An eleven terminal barrier strip mounted on the rear panel provides Output, Sensing, Remote Programming, and ground connections. The unit is shipped with shorting links in place across terminals 1 and 2, 3 and 4, 6 and 7, and 9 and 10. In this configuration, local programming and sensing at the rear terminals is provided. Consult Supplementary Controls table 2 - 2 for details concerning link connection changes required to provide remote sensing or programming.

2.2.3 Output, Front Panel:

Five binding post connectors mounted on the front panel provide Output, Sensing, and Ground connections. Special shorting links are provided, but are not attached to the unit at time of shipment. In this configuration, Remote Sensing is available from the front panel connectors. See paragraph 2.4.2 below for front terminal sensing connections.

NOTE: Sensing and regulation of the output may be made locally or remotely from either the front or rear sensing terminals. However, rated regulation can be maintained only at one set of Sensing terminals at a time. Should both front and rear terminals be used simultaneously load regulation will deteriorate severely.

2.3 CONTROLS

2.3.1 Front Panel

TABLE 2-1 FRONT PANEL CONTROLS

SYMBOL	NAME	FUNCTION
S1	AC POWER	Toggle switch, controls input power
R37	VOLTAGE ADJUST (Coarse)	Potentiometer, adjusts voltage output
R38	VOLTAGE ADJUST (Vernier)	Potentiometer, adjusts voltage output
R62	CURRENT ADJUST (Coarse)	Potentiometer, adjusts current
R61	CURRENT ADJUST (Vernier)	Potentiometer, adjusts current

2.3.2 Internal

TABLE 2-2 INTERNAL CONTROLS

SYMBOL	NAME	FUNCTION
R36	Minimum Voltage Adjust	Adjusts minimum voltage, with front panel controls fully CCW
R49	Ammeter Adjust	Adjusts ammeter calibration
R55	Pre-Regulator Adjust	Adjusts voltage across Series Pass
R74	Reference Adjust	Adjusts nominal reference voltage
R76	Minimum Current Adjust	Adjusts minimum current, with front panel controls fully CCW
R78	Maximum Current Adjust	Adjusts maximum current, with front panel controls fully CW

2.4 SUPPLEMENTARY CONTROLS (Shorting Links)

2.4.1 Rear Panel

TABLE 2-3 SHORTING LINK APPLICATION, REAR PANEL

TERMINALS	CONDITION	FUNCTION
1 and 2 6 and 7	Shorted Shorted	Local sensing and regulation at rear panel output terminals
1 and 2 6 and 7	Not Connected Not Connected	Remote sensing and regulation at load or front panel operation
3 and 4 4 and 5	Shorted Open	Voltage programmed locally, output dependent upon volt. adj. pots
3 and 4 4 and 5	Ext. PGM res. Shorted	Voltage programmed remotely, output dependent upon size of PGM resistor
9 and 10 8 and 9	Shorted Open	Current programmed locally, output dependent upon current adj. pots
9 and 10 8 and 9	Ext. PGM res. Shorted	Current programmed remotely, output dependent upon size of PGM resistor

NOTE: 1) If remote current programming terminals (9 and 10) are left open, the output current will be zero.

2) If remote voltage programming terminals (3 and 4) are left open, the output voltage will become unregulated.

3) See paragraph 1.2.4 for approximate PGM resistor scale factors.

2.4.2 Front Panel

TABLE 2-4 SHORTING LINK APPLICATION

TERMINALS	CONDITION	FUNCTION
(-S) and (-V) (+S) and (+V)	Shorted Shorted	Local sensing and regulation at front panel output term. NOTE (1
(-S) and (-V) (+S) and (+V)	Open Open	Remote sensing and regulation at load (four leads used). NOTE (2

NOTE: 1) If a locally sensed output is to be taken from the front panel terminal posts, the corresponding rear panel terminals must have their shorting links removed.

2) If a remotely sensed output is to be taken from the front panel terminal posts, both the Output and Sensing leads must be taken from the front panel.

2.5 OPERATION

2.5.1 Control Settings

Set all front panel controls fully CW so that unit will operate in the Voltage rather than Current Limiting mode.

2.5.2 Shorting Links

If Local Sensing rather than Remote Sensing operation is desired, ascertain that shorting links are in place across either the appropriate front or rear terminals, but not across both front and rear terminals at the same time.

2.5.3 Grounding

Either side of the Output may be grounded, or the Output may be used in a floating condition.

2.5.4 Power On

Connect the line cord to a suitable source of 115 VAC, 60 cycle power. Set POWER switch S1 to AC-ON, and observe that pilot lamp DS1 glows.

2.5.5 Warm-Up

No warm-up time is necessary to place the unit into operation. However, a 30 minute warm-up period is recommended to reach rated stability.

2.5.6 Series Operation

To operate two or more power supplies in a series configuration, connect the output of each power supply in series. When operating in this mode, it is necessary to adjust the output of each unit independently. The output voltage is equal to the sum of the voltage settings of each power supply.

2.5.7 Parallel Operation

A) With rated resistive load connected across the output of power supply A as shown in Figure 2-1A, set VOLTAGE ADJUST control to desired output voltage (E_{01}), and set CURRENT ADJUST control for maximum rated output current.

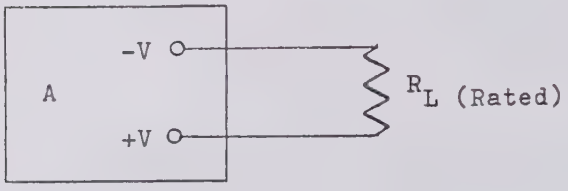


FIGURE 2-1A

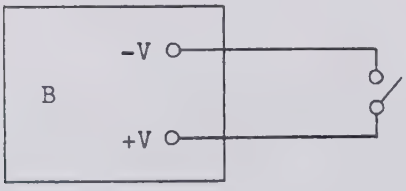


FIGURE 2-1B

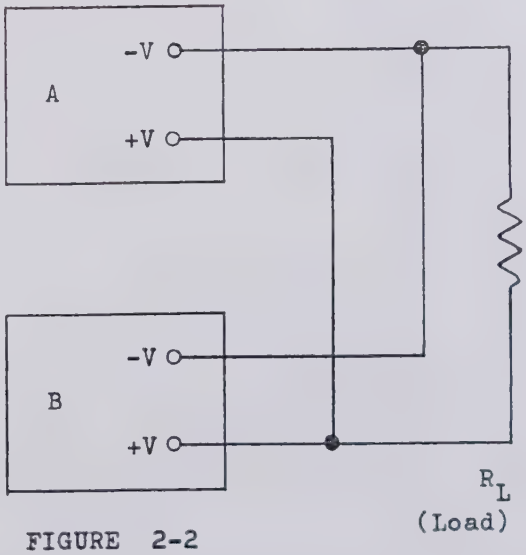


FIGURE 2-2

2.5.7 Parallel Operation (Continued)

B) Connect power supply B as shown in Figure 2-1B. With no load across the output, set VOLTAGE ADJUST control for an output voltage (E_{02}) 2 volts higher than the output voltage (E_{01}) of power supply A. Place a short across the output terminals, and set the CURRENT ADJUST control for 1/2 the total load current requirement.

C) Remove all former output loads and connect the outputs of power supplies A and B in parallel with each other, and in parallel with the load, as shown in Figure 2-2

D) If parallel operation of these two power supplies is desired for a systems application, it is important that both units be turned on simultaneously. It is therefore recommended that both power supplies be connected to a single large circuit breaker. Maximum output current will be twice that of either of the two power supplies, while minimum output current will be that of power supply B, or half the total load current.

NOTE: If parallel operation of Trygon power supplies utilizing overvoltage (OV) protection is desired, consult the factory for special instructions.

2.6 OPERATIONAL TEST PROCEDURE

2.6.1 Equipment Required (or equivalent)

(A) Oscilloscope, Tektronix Type 561
(B) Differential Amplifier Plug In, Tektronix Type 63
(C) Time Base Plug In, Tektronix Type 67
(D) Differential VTVM, Fluke Model 825A
(E) AC VTVM, Hewlett Packard Model 400D
(F) VOM, Simpson Model 260
(G) Variable Auto Transformer, Superior Electric Company, Powerstat Type 3PN136 (20 ampere rating)

2.6.2 Power Off

A) General

Prior to connecting the test equipment or resistive loads to the unit, measure the resistance across the output terminals. Due to the presence of Reverse Voltage Protective Diode CR24, a difference in resistance values will be seen when ohmmeter polarity is reversed. If the positive test lead of the ohmmeter is connected to the negative output terminal and the negative test lead is connected to the positive output terminal, Protective Diode CR24 will be forward biased. The maximum resistance measured across the output terminals in this configuration should not exceed 100 ohms. Reversing the test leads will of course back bias the diode. The minimum resistance measured now should exceed 500 ohms. Measure the resistance between the output terminals and chassis ground, and observe that at least 20 MEG OHMS of resistance appears between these points.

B) Test Set Up

It is of the utmost importance that AC power lines, breaker boxes, and connectors used in the input wiring to power supplies be of sufficient size to handle the peak AC current which may flow through them. Serious losses in regulation and an increase in ripple may result from under rated or over loaded input lines. The AC impedance from the breaker box to the power supply input should not exceed 3/4 ohms. All AC power input line connections should be securely tightened, and any movable electric contact surface (such as the wiper arm of a variable transformer) should be kept clear of high impedance producing oxide coatings.

Connect shorting links across either the front or rear (but not both) output and sensing terminals. To reduce pick up, shielded wire must be used for all connections between test equipment and the power supply being tested. To prevent ground loops, it is important that only one ground connection be made, as shown in Figure 2-3 and Figure 2-4. Tighten all terminal connections as securely as possible, and set all front panel controls fully CW.

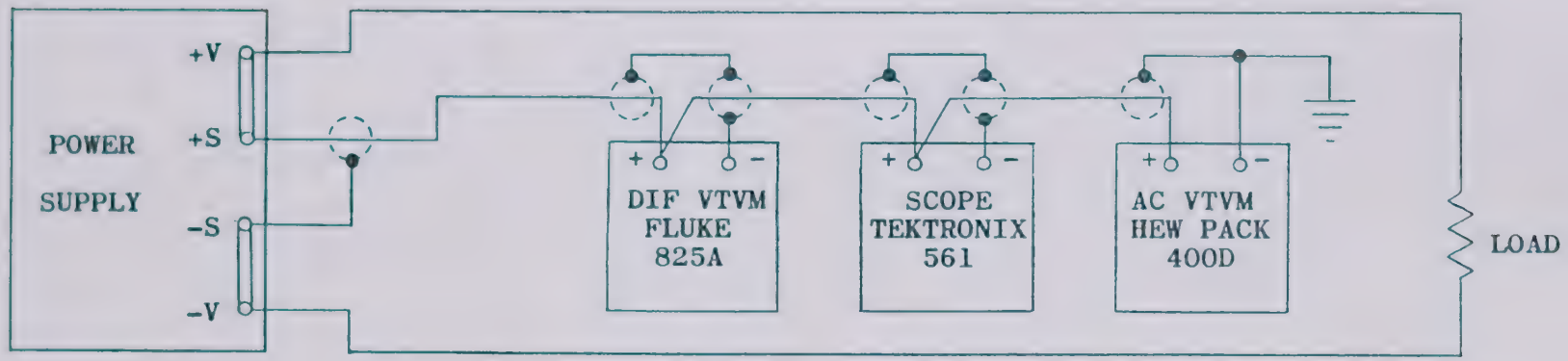


FIGURE 2-3
CONSTANT VOLTAGE OPERATION

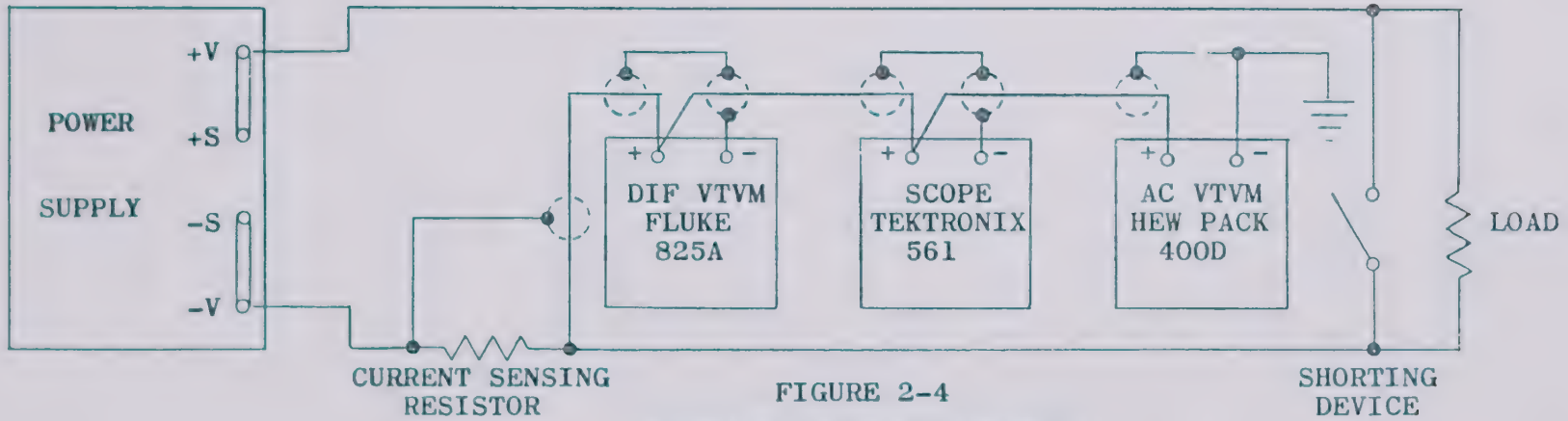


FIGURE 2-4
CONSTANT CURRENT OPERATION

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2.6.3 Power On

A) Maximum Voltage Control

Connect unit to a suitable source of 115 VAC (nominal) input voltage and set AC POWER Switch to ON. Observe that pilot lamp glows and that unit and test voltmeters indicate full output voltage. Vary voltage controls and observe that output voltage varies as indicated on unit and test voltmeters.
NOTE: If partial rotation of the VOLTAGE ADJUST controls produces no apparent change in indicated output voltage, further rotation of these controls should not be attempted. Rotation of these controls fully CCW with little or no output voltage regulation can result in damage to the controls, the load, or both. Set the AC POWER switch to OFF, and proceed with the trouble shooting outlined in paragraph 4.3.4 (Poor Regulation) of the MAINTENANCE SECTION of this instruction manual.

B) Minimum Voltage Control

Set voltage controls fully CCW and observe that the voltage indicated on the unit and test voltmeters drops below the zero setting of the meters. The output voltage should be approximately negative 200 MV. Reset voltage controls fully CW.

2.6.4 Constant Voltage Operation

A) Load Regulation

With the equipment connected as shown in Figure 2-3, connect a suitable load resistance across the Output terminal connections. The load resistance selected must be able to dissipate the rated power of the unit (P = EI) and must be of sufficient value to yield the rated output current when the rated voltage is applied. Note the voltage indicated on the Differential VTVM. Disconnect the resistive load from the output. The maximum change in output DC voltage indicated on the Differential VTVM should not exceed by more than 0.01% or 3mv (whichever is greater) that of the output voltage indicated with the load resistance applied across the output terminals.

2.6.4 Constant Voltage Operation (Continued)

B) Line Regulation

Place the resistive load across the output and note the voltage indicated on the Differential VTVM. Vary the input line voltage between 105 and 125 VAC. The maximum change in output voltage should not exceed by more than 0.01% or 2mv (whichever is greater) that of the output voltage measured at nominal input line voltage.

C) Ripple Voltage

With the resistive load connected across the output terminals, measure the AC ripple with the AC VTVM. Vary the input line voltage between 105 and 125 VAC. The maximum ripple amplitude should not exceed .5mv RMS.

2.6.5 Constant Current Operation

A) Load Regulation

With the equipment turned off, disconnect the resistive load from the output terminals. Connect a small current sensing resistor in series with the resistive load and then connect the load back across the output terminals. Selection of the proper value for the current sensing resistor may be easily made using the formula $R_S = \frac{1}{I_R}$ where R_S = Value of Current Sensing Resistor and I_R = Rated Load Current. Connect the equipment as shown in Figure 2-4, and apply power to the power supply.

Vary the VOLTAGE ADJUST controls and resistive output load as necessary, to achieve rated current and voltage output. Decrease the load resistance until current meter reading exceeds full scale indication. Rotate CURRENT ADJUST control CCW to return the current meter reading to full scale. Observe that the output voltage has decreased from its previous full scale reading, and that increasing the VOLTAGE ADJUST controls has no effect upon the output voltage or current. This indicates that the unit is now operating in the Constant Current Mode.

Measure the voltage across the small sensing resistor. Compute and note the current flow through this resistor. Change

2.6.5 Constant Current Operation (Continued)

the output load from the resistive load previously used, to a short. Again measure the voltage across the small sensing resistor and compute the value of the current flow through this resistor. The change in current should not exceed by more than 0.5% or 10ma (whichever is greater) that previously noted with a full resistive load across the output.

B) Line Regulation

Replace the resistive load across the output and measure the voltage drop across the small sensing resistor. Compute and note the current flow ($I = \frac{E}{R}$) through this resistor.

Vary the input line voltage between 105 and 125 VAC. Note the maximum change in voltage across the sensing resistor and compute the maximum current flow. The maximum change in current should not exceed by more than 0.5% or 10ma (whichever is greater) that previously noted at nominal input line voltage.

C) Ripple Current

With the AC input line voltage adjusted to the nominal value of 115 volts and the resistive load connected across the output, measure the amplitude of the AC ripple as seen across the sensing resistor with the AC VTVM. Compute and note the current flow. Vary the AC input line voltage between 105 and 125 VAC. Measure the maximum voltage drop and compute the maximum current flow. The maximum ripple current must not exceed by more than 0.25% or 5ma (whichever is greater) that of the current flow noted during nominal input line voltage.

SECTION III - THEORY OF OPERATION

3.1 GENERAL

The purpose of the power supply is to transform, rectify and filter the AC input into a well regulated, stable, and adjustable, DC output. In performing these functions, the circuitry of the unit may be broken down into four major sections, which shall be referred to in the following order:

1) Power Input
2) Reference Supply
3) Series Regulator
4) Pre-Regulator

3.2 BLOCK DIAGRAM ANALYSIS

The circuitry of this power supply is illustrated in simplified form in the BLOCK DIAGRAM. As each basic circuit is described, it will be advantageous to refer to the fold out BLOCK DIAGRAM and SCHEMATIC DIAGRAM located in the APPENDICES of this instruction manual.

3.2.1 Input Transformer and Rectifiers (Power Input)

The input section consists of Power Transformer T1, full wave rectifier diode sets CR1 and CR2, CR3 and CR4, CR5 and CR6 and CR12 and CR13, and filter capacitors C1, C2 and C9. Each rectifier set provides the necessary DC voltages to the various power supply sub-sections.

3.2.2 Reference Supply

The 15 volt series regulated Reference Supply provides a stable reference voltage for the comparator circuit and error amplifier circuits.

To maintain a 15 volt output from the Reference Supply,

3.2.2 Reference Supply (Continued)

a sample of the output voltage is derived from the voltage divider comprised of R10, R74 and R60. This voltage is compared with the voltage across zener diode CR10. A differential Amplifier, Q4 and Q5, acts as a comparator between the two voltages. The output of the amplifier is fed into a second differential amplifier stage comprised of Q3 and Q16. The output from the collector of Q3 provides the signal to an emitter follower, Q2. The output of the emitter follower, in turn, provides the DC signal to series regulator Q1. As the signal to Q1 changes, the current from collector to emitter changes, maintaining a constant voltage across capacitor C4. This is the reference voltage that is used for the error sensing amplifier, constant current generator and comparator.

3.2.3 Series Regulator

A) General

The primary function of the Series Regulator is to maintain the output voltage at its set level regardless of variations of input line voltage (within specified limits) or variations in load current up to the pre-set level. In addition, the Series Regulator provides constant load current when a preset current level is attained, and provides short circuit protection as well.

The Series Regulator circuit is comprised of 4 basic sub-circuits. This sub-circuitry consists of a Voltage Sensor and Comparator, a Current Sensor and Comparator, and Error Signal Amplifier and Driver and the Series Pass, by means of which the actual adjustment of output voltage is implemented.

B) Voltage Sensor and Comparator

The voltage sensing and comparison is accomplished by Differential Amplifier Q13 and Q14 and associated circuitry. The Differential Amplifier compares a sample of the output voltage with a stable reference voltage, and amplifies the difference. R29, R30, R34 and R35 form a bridge circuit which is balanced by the operation of the Series Regulator. Any unbalance caused by

3.2.3 Series Regulator (Continued)

a change in voltage at either the negative sensing terminal (-S) or across the voltage adjustment circuitry (R36, R37 and R38), will appear as a differential voltage between the bases of Q13 and Q14. This differential voltage is amplified and then used to adjust the voltage drop in the Series Pass to re-balance the bridge.

C) Error Signal Amplifier and Driver

The Error Signal Amplifier amplifies any signal generated in the Differential Amplifier by an unbalance of the bridge. This signal is fed through CR18 to Error Amplifier Q12, where it is amplified and fed to the base of Driver Q21 and then to Driver Q20. The driver stages provide additional current gain and buffering. The error signal is fed from the emitter of Driver Q20 to the Series Pass network.

D) Series Pass*

The Series Pass consists basically of transistors Q15 and Q17 and their associated circuitry, which are in series with both the input power source and the output. It is driven by the amplified error signal and is used to increase or decrease the output signal by varying its conduction, and therefore its effective resistance.

Series Pass transistor Q15 is in parallel with a relatively large current handling "throw off" resistor R57, which minimizes power dissipation in the transistor, thereby prolonging transistor life expectancy and increasing unit reliability.

In this circuit, Q17 conducts for all conditions of load current. However, under relatively low current conditions, when Q17 is not in saturation, Q15 will be cut off, by virtue of the higher voltage between the emitter and collector of Q17 than across CR28. As the load current increases and the voltage between the collector and emitter of Q17 decreases (due to the increased voltage drop across R57), Q15 will conduct harder, thereby causing the load current to be partially diverted. The higher the load current becomes, the harder Q15 conducts. In this way, the Series Pass

*Patents Pending

3.2.3 Series Regulator (Continued)

circuit may be considered to be a variable resistor whose value is adjustable by the error signal.

E) Current Regulation

Load current regulation is achieved by regulating the voltage across Current Sensing Resistor R45. As the load current through this resistor increases, so does the voltage. The reference voltage against which this voltage is compared is developed across R22, and is proportional to the reference supply voltage. In order to raise the voltage across R45 to the D. C. level required to forward bias CR19, an additional voltage is added to the negative end of R45. This is the voltage developed across CURRENT VERNIER control R61, CURRENT ADJUST control R62, and R63. R61 and R62 have been made variable so that the desired maximum current can be pre-set.

When the voltage across R45 becomes great enough to forward bias CR19, CR18 becomes reverse biased, thereby disconnecting the voltage regulating circuits. The difference signal resulting from a comparison of the voltage developed across R45 and the reference voltage is amplified and used to control the effective resistance of the Series Pass, to maintain constant voltage across R45, which in turn maintains a constant load current.

3.2.4 Pre-Regulator

A) Overall Operation

The purpose of the Pre-Regulator is to maintain the unregulated input voltage (voltage of the input capacitor) approximately 9 to 15 volts (depending upon load conditions) higher than that of the output voltage, in order to keep the power dissipation across the Series Pass section of the series regulator at a reasonable level. The device used to regulate the input voltage applied to the input capacitor is the SCR (Silicon Controlled Rectifier). The SCR, basically a gated diode, operates only when forward biased and triggered by a positive gate. The

3.2.4 Pre-Regulator (Continued)

positive gating signal is derived from a pulse transformer which is driven from a comparator circuit. This circuit compares samples of the input and output voltages and determines the proper time for the SCR gate to be applied.

In order for pulse transformer T2 to develop the gating signal for the SCR, Q7 and Q8 must both be made to conduct. Inhibit gate Q7 is controlled by Inhibit Amplifier Q6, which in turn is programmed by the differentiating network composed of R12 and C5. The input signal to this differentiating network is derived from Inhibit Rectifiers CR12 and CR13. The positive portions of the differentiated signal do not allow conduction of Q6, but the negative portions do. Conduction of Q6 in turn causes conduction of Q7. Therefore, as Q6 conducts only during the time the negative portion of the differentiated wave is applied to its base, the Inhibit circuit prevents any pulse from being developed across pulse transformer T2 at any time other than during the latter half of each half cycle of the input wave. Transistors Q8 and Q9 form a differential amplifier stage. R18 and R19 establish a fixed reference for the base of Q9, which in turn fixes the emitter potential of Q8 and Q9. The base signal for Q8 is derived from the voltage divide network consisting of R56, R55 and R65, in the input circuit. As the input signal swings from zero volts to peak negative and then back to zero, a point is reached at which Q8 becomes forward biased. When Q8 conducts, Pulse Transformer T2 can pass a gating pulse through to the SCR. As long as the input and output voltages remain constant, the SCR will continue to fire at the same time during the latter half of each cycle. However, if there should be a change in either input or output levels, the SCR will fire at a correspondingly earlier or later time, so as to increase or decrease the potential to which the input capacitor may charge.

B) Silicon Controlled Rectifier Operation

The SCR (Silicon Controlled Rectifier) is a semi-conductor device similar in many respects to an ordinary diode. In function, however, it comes closest to being the solid state equivalent of a

3.2.4 Pre-Regulator (Continued)

gas filled thyratron. Perhaps the most significant difference in operation between the SCR and the thyratron is the fact that the SCR is a current-triggered device, whereas the thyratron is a voltage controlled device.

The SCR is a 3 terminal PNPN device in which the internal P region is brought out externally in the form of a gate lead. The gating signal fed into the gate lead serves to cause the SCR to conduct. As the gating signal is always of a low amplitude in relation to the normal power handling ability of the SCR, the gate lead is easily distinguishable by its relatively small physical size. Its function is similar to that of a switch.

The main purpose of the SCR is to function as a regulating device controlling the amount of voltage developed across the input capacitor. The voltage across the input capacitor is maintained at a relatively low fixed level above that of the output capacitor. The difference in voltage usually varies between 9 and 15 volts D. C., depending upon load conditions. Power dissipation in the series pass is thus kept at a reasonable level, thereby prolonging the life expectancy of the series pass transistors.

The input capacitor can charge only after the SCR is "fired" or gated on. Gating signals for the SCR are purposely restricted from occurring during the first half of the rectified half cycle by an inhibit circuit, as the SCR and associated circuitry cannot maintain control during the first half of the cycle. The level to which the input capacitor can charge is determined entirely upon what portion of the half cycle the SCR is "fired" at. If the gate occurs very near the peak of the rectified voltage, the input capacitor would charge to full voltage. Similarly, if the gating signal occurs at a later time during the latter half of the rectified wave, the capacitor voltage would be correspondingly lower.

3.3 OPTIONAL FEATURES

The standard Medium Power Half Rack Series may be equipped with one or both of two standard options, overvoltage protection (suffix OV) or a high stability feature (suffix X).

3.3.1 Overvoltage Protection (OV)

The overvoltage protection circuit incorporates a fail-safe silicon controlled rectifier, CR32, section that applies a short circuit across the output when the output voltage attempts to rise more than 5% or 1.5 volts above the programmed voltage. A sensitivity control is provided on most units to increase the voltage differential causing the (OV) trip.

If the overvoltage condition is caused by a failure in the series pass, the SCR will conduct to cause a short circuit across the output. Since such a component failure would disable the short circuit protection of the supply, a fuse, F3, in series with the series pass opens to shut off the supply. This fuse is located within the supply and should not be replaced until the faulty component is changed.

If the overvoltage condition is caused by a line transient or a voltage feeding back into the supply, the CR32 will conduct resulting in a short circuit across the output of the supply. In this case, the short will activate the overload protection circuit of the supply, causing the supply voltage and current to drop to nominal zero. The supply can be reset by removing the source of overvoltage and turning the "AC" switch off and on again.

NOTE: It should be noted that while the overvoltage protection (OV) is an optional feature on Trygon supplies, all units are equipped with short-circuit protection as part of the standard unit.

3.3.2 High Stability (X)

Power supplies equipped with the High Stability option utilize low temperature coefficient components in the comparator section, providing 0.01%/°C temperature coefficient and 0.01% stability.

SECTION IV - MAINTENANCE

4.1 GENERAL

Contained herein is a systematic procedure to serve as a guide when troubleshooting a power supply.

Below is a list of recommended test equipment. It is the same type of equipment that Trygon employs at the factory. Equipment that is electrically equivalent may be substituted.

4.2 TEST EQUIPMENT REQUIRED (or equivalent)

1 Oscilloscope, Tektronix Model 560 or Model 561
1 Volt Ohmmeter, Simpson Model 260

4.3 TROUBLESHOOTING

A) General

If specialized test equipment is not available, transistors and diodes may be checked with an ohmmeter. When checking diodes which have been removed from the circuit, the minimum acceptable front to back resistance ratio should be 1000 to 1. Transistors should be checked with the ohmmeter resistance range selector switch set to the lowest (R x 1) scale.

B) Transistor Bias Voltage

Transistor bias voltage is usually measured between the base and emitter. When a transistor is removed from a circuit and checked with an ohmmeter, the biasing voltages are provided by the battery in the ohmmeter. The polarity of the ohmmeter test leads determine the type of bias applied to the transistor. For example, when checking an NPN transistor, connecting the positive test lead to the base, and the negative test lead to the emitter will forward bias the transistor, while reversing

the leads will of course reverse bias it. If a PNP transistor is to be checked, connecting the positive lead to the emitter and the negative lead to the base will forward bias it and reversing the test leads will cause it to become reverse biased. If a transistor is forward biased, and further increases of input signal have no apparent effect upon the output signal, the transistor is in a state of saturation. This condition exists when the voltage between the collector and emitter is equal to or less than the bias voltage. Relative resistance values may be checked against those listed in Relative Resistance Measurement Table 4-1.

TABLE 4-1 RELATIVE RESISTANCE VALUES

COMPONENT	RESISTANCE	FORWARD BIASED	REVERSE BIASED
Transistor	Collector-Emitter	High	High
	Collector-Base	Low	High
	Emitter-Base	Low	High
Diode	Anode-Cathode	Low	High
SCR	Anode-Cathode	High	High
	Gate-Cathode	Low	High

C) Power Off Checks

Inspect the unit for loose plug in components, faulty grounds, broken wires, broken solder joints, foreign matter and open fuses. Connect shorting links across terminals 1 and 2, 3 and 4, 6 and 7, and 9 and 10. Set all front panel controls fully CW. Measure resistance as outlined in paragraph 2.6.2 (A).

4.3 TROUBLESHOOTING (Continued)

D) Power On Checks

If resistance measurement appears correct, apply power to the unit. If either fuse should open upon having power applied to the unit, return the AC POWER switch to OFF, and check all full wave rectifiers, input capacitors and the power transformer for a short circuited condition. If neither fuse opens when power is applied, measure the voltages across the Zener diodes, carefully observing diode and meter polarity.

TABLE 4-2 ZENER DIODE VALUES

DIODE	PART NUMBER	VOLTAGE
CR10	SV515	6.5 VDC ±5%
CR20	UZ815	15.0 VDC ±10%

Ascertain the presence of the reference voltage across capacitor C4. This voltage should be approximately -15 VDC, as measured from the negative side of C4 to -S. If this voltage is not present, or if it varies, refer to the section dealing with the Reference Supply.

4.3.1 Reference Supply

A) Unregulated Output (C2 and C4 voltages almost equal)

Comparator Stage

1. If the output of the reference supply is unregulated, Q5 should be saturated.
2. If Q5 is not saturated, check zener diode CR10 for proper operation. The correct voltage across CR10 should fall within a range of 6.1 VDC and 6.8 VDC.

3. If the trouble does not seem to lie with CR10, check that resistors R74, R60 and R7 are not open.

4. If R74, R60 and R7 are not open, determine that the collector of Q5 is not open.

Voltage Amplifier Stage

1. If the required voltage measurements have been obtained as outlined in the check of the preceeding stage, Q3 should be in a state of saturation.

2. If Q3 is not saturated, check for the existance of a short between the collector and emitter of Q16.

3. If Q16 is not shorted, check that R5 is not open.

Driver And Series Pass Stage

1. If the required voltage measurements have been obtained as outlined in the check of the preceeding stage, Q1 and Q2 should be reverse biased.

2. If Q2 is saturated rather than cut off, check that the collector of Q3 is not open.

3. If Q1 is saturated rather than cut off, check that the collector and emitter of Q2 are not shorted.

4. Check that a short does not exist between the collector and emitter of Q1.

B) Very Low Output Voltage

Comparator Stage

1. If the reference supply output voltage is very low, check that fuses F1 and F2 are not open.

2. If the fuses are not open, check zener diode CR10 for proper operation. The correct voltage across CR10 should fall within a range of 6.1 VDC to 6.8 VDC.

3. If CR10 is operating properly, the voltage across R7 should be approximately 0.7 VDC less than the voltage

Comparator Stage (Continued)

measured across CR10. If the difference between the voltages exceeds 0.7 VDC, check for an open emitter or base of transistor Q4.

4. If the voltage across R7 is of the proper amplitude, Q5 should be reverse biased.

5. If Q5 is not reverse biased, check that R10 is not open.

Voltage Amplifier Stage

1. If the required voltage measurements have been obtained as outlined in the check of the preceeding stage, Q3 should be reverse biased.

2. If Q3 is not reverse biased, check that a short does not exist between the collector and emitter of Q5.

3. If Q5 is not shorted, check that the collector and emitter of Q16 are not open.

Driver and Series Pass Stage

1. If the required voltage measurements have been obtained as outlined in the check of the preceeding stage, Q2 and Q1 should be saturated.

2. If Q2 is reverse biased, check that the collector and emitter of Q3 are not shorted.

3. If Q3 is not shorted, check that CR7 and CR8 are not shorted.

4. If CR7 and CR8 are not shorted, check that R1 and R4 are not open.

5. If Q1 is reverse biased, check that the collector and emitter of Q2 are not open.

4.3.2 Pre-Regulator

1. Measure the voltage across capacitor C9. The voltage should measure about -75 volts D.C.

4.3.2 Pre-Regulator (Continued)

2. If capacitor C9 has no voltage across it, observe the waveshape across diode CR16. Be sure that the oscilloscope probe goes to the CR16 anode and the probe ground lead to the CR16 cathode. The waveshape should be as shown below:

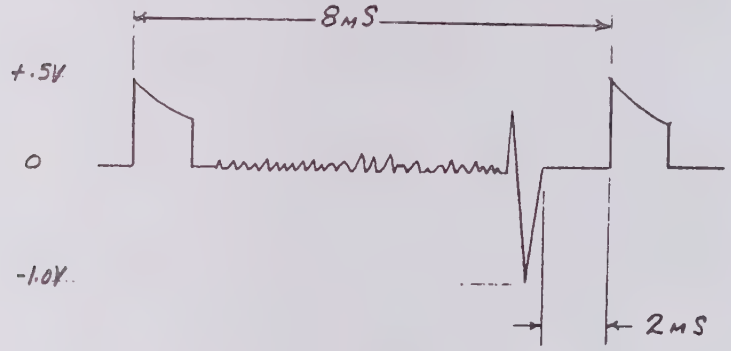


FIGURE 4-1

3. If the waveshape, as shown above, is not present, measure the voltage from the cathodes of CR12 and CR13 to the -S terminal on the rear barrier strip. The voltmeter should read about +19 volts D.C.

4. If the +19 volts is present, go to step 5. If not, measure the A.C. across pins 6 and 8 of T1 for about 40 volts RMS.

5. Check across resistor R14 with an oscilloscope for the waveshape shown below in Fig. 4-2. If the signal is not present, the fault will lie in the Q6 and Q7 stages.

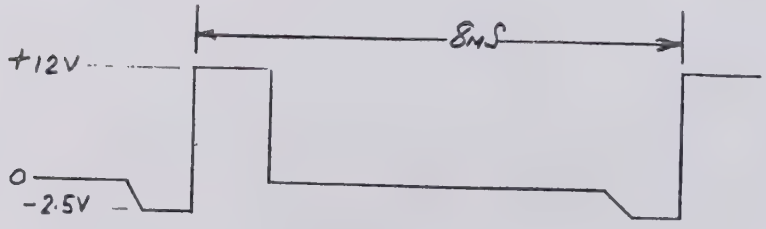


FIGURE 4-2

6. Place an oscilloscope from the collector to the emitter of transistor Q8. The waveshape should

4.3.2 Pre-Regulator (Continued)

appear as shown below in Fig. 4-3. If the signal is not present, the fault will lie in the Q8 and Q9 stages.

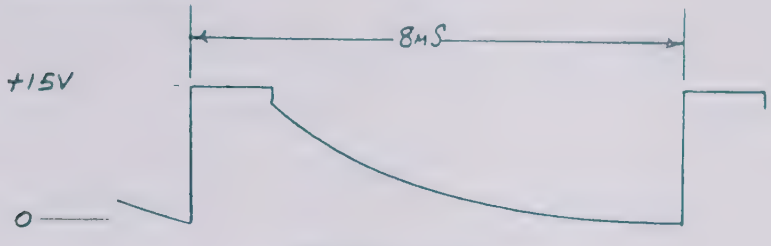


FIGURE 4-3

4.3.3 Low or No Output Voltage

1. If either the pre-regulator or series regulator circuits cease functioning, the output voltage will drop below its normal level or fall to zero.

2. Correct operation of the pre-regulator may be determined by examining the wave shape at the gate lead. Place the oscilloscope probe at the gate lead of CR35 and the oscilloscope ground lead on the cathode of the SCR, CR35.

3. A series of positive pulses will be seen on the oscilloscope, as illustrated below in Fig. 4-4:

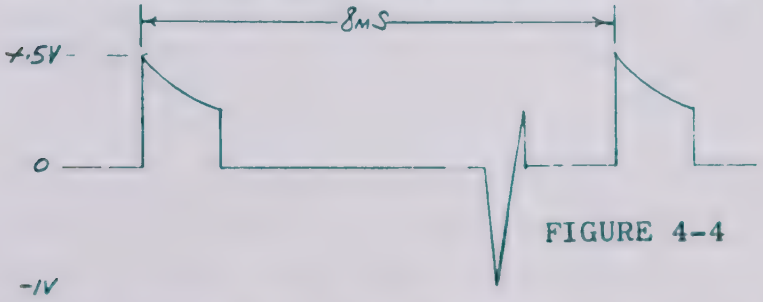


FIGURE 4-4

If the wave shape and amplitude are not as shown above, refer to the section on pre-regulator trouble-shooting.

4. Measure the voltage across capacitor C9. It should

4.3.3 Low or No Output Voltage

be approximately -55VDC. Be sure to observe correct meter and capacitor polarity.

5. If the voltage across C9 is less than 50 volts D. C. or zero, measure the voltage across pins 3 and 5 of transformer T1 for approximately 125 volts A.C.

6. After determining that the preregulator and the main rectifiers, CR5 and CR6, are operating properly, measure the bias voltages listed in the Table of Bias and Saturation Voltages 4.3.5.

7. Measure each transistor bias in turn. The stage that has the incorrect bias (opposite to values in the table) indicates that the preceding stage is at fault.

4.3.4 Poor Regulation

1. If the error sensing circuit or the series regulator should stop functioning, the output voltage would be unregulated.

2. The correct functioning of these circuits may be determined by following, step by step, the procedure for checking transistor bias voltages as outlined in section 4.3.5.

3. Check each transistor, in turn, for the indicated bias condition. When a stage is found to be reversed biased (other than shown in the table) look for the trouble in the preceding stage.

4.3.5 Transistor Bias and Saturation Voltages

In the event of a malfunction of the unit causing either a no output or an unregulated output condition, the following transistor bias and saturation voltages may be expected to be encountered. If during any portion of the testing sequence listed below a voltage measurement similar to that listed in the table cannot be obtained, the probable cause of the malfunction will be found in the stage preceeding that having the incorrect voltage measurement.

4.3.5 Transistor Bias and Saturation Voltages (Cont.)

TABLE 4-3 TRANSISTOR BIAS AND SATURATION VOLTAGES

TEST SEQUENCE	TRANSISTOR	NO OUTPUT	UNREGULATED OUTPUT
1	Q14	V_{BE} Reverse Biased	V_{BE} +0.7 VDC $V_{CE} \leqq$ 0.5 VDC
2	Q13	V_{BE} +0.7 VDC $V_{CE} \leqq$ 0.5 VDC	
3	Q12	V_{BE} +0.7 VDC $V_{CE} \leqq$ 0.5 VDC	V_{BE} Reverse Biased
4	Q11	V_{BE} -0.3 VDC	V_{BE} -0.3 VDC
5	Q21	V_{BE} -0.3 VDC	V_{BE} Reverse Biased
6	Q20	V_{BE} -0.3 VDC	V_{BE} Reverse Biased
7	Q17	V_{BE} -0.3 VDC	V_{BE} Reverse Biased
8	Q10	V_{BE} +0.7 VDC	V_{BE} +0.7 VDC
9	Q29	V_{BE} +0.7 VDC	V_{BE} +0.7 VDC

NOTE: V_{BE} indicates bias measurement

V_{CE} indicates saturation measurement

SECTION V - CALIBRATION

5.1 GENERAL

The following adjustments should be made periodically to assure optimum operating characteristics and maximum efficiency of the Trygon power supply.

5.2 TEST EQUIPMENT REQUIRED (or equivalent)

(A) Oscilloscope, Tektronix Type 561
(B) Differential Amplifier Plug In, Tektronix Type 63
(C) Time Base Plug In, Tektronix Type 67
(D) Differential VTVM, Fluke Model 825A
(E) AC VTVM, Hewlett Packard Model 400D
(F) VOM, Simpson Model 260
(G) Variable Auto transformer, Powerstat Type 3PN136 (20 Ampere rating)

5.3 CALIBRATION PROCEDURE

5.3.1 Reference Supply

The reference voltage level is adjusted by means of Reference control R74. This potentiometer should be adjusted for a voltage amplitude of negative 15 VDC as seen across capacitor C4. All control voltages are derived from this reference voltage. If it is necessary to adjust this voltage, it is very probable that it will be necessary to adjust the following listed sections as well.

5.3.2 Pre-Regulator

A) With power supply operating without a resistive load across the output terminals, vary VOLTAGE ADJUST control until 50% of rated voltage output is indicated on the D.C. voltmeter.

5.3.2 Pre-Regulator (Continued)

Set POWER ON switch S1 to OFF, and connect resistive load across the output terminals. Set POWER ON switch S1 back to ON, and adjust resistive load for rated current setting on ammeter.

B) Set oscilloscope to D. C. triggering mode and connect scope input across the negative terminal of input capacitor C9 and output capacitor C8.

C) Adjust R55 for a voltage amplitude of 9 VDC and note that the 120 cps ripple voltage appears balanced.

D) Vary AC input line voltage between 105 and 125 VAC. Observe that the 120 cps ripple remains balanced and does not vary in amplitude more than 20% of the pre-set value (9 volts).

5.3.3 Minimum Voltage

To adjust power supply output for minimum output voltage, set VOLTAGE VERNIER control R38 fully CCW. Adjust Minimum Voltage control R36 so that the voltage measured across the output terminals is a negative 200mv.

5.3.4 Minimum Current

Connect test ammeter, having a full scale current indicating capacity of 100 ma, across output terminals in place of a load resistor. Set all front panel controls fully CCW and apply power to the unit under test. Slowly rotate VOLTAGE ADJUST control in a CW direction, until current meter indicates a current flow somewhere between 0-50ma. Adjust Minimum Current control R76 for a nominal current indication of 25 ma. Set POWER ON switch S1 to OFF.

5.3.5 Maximum Current

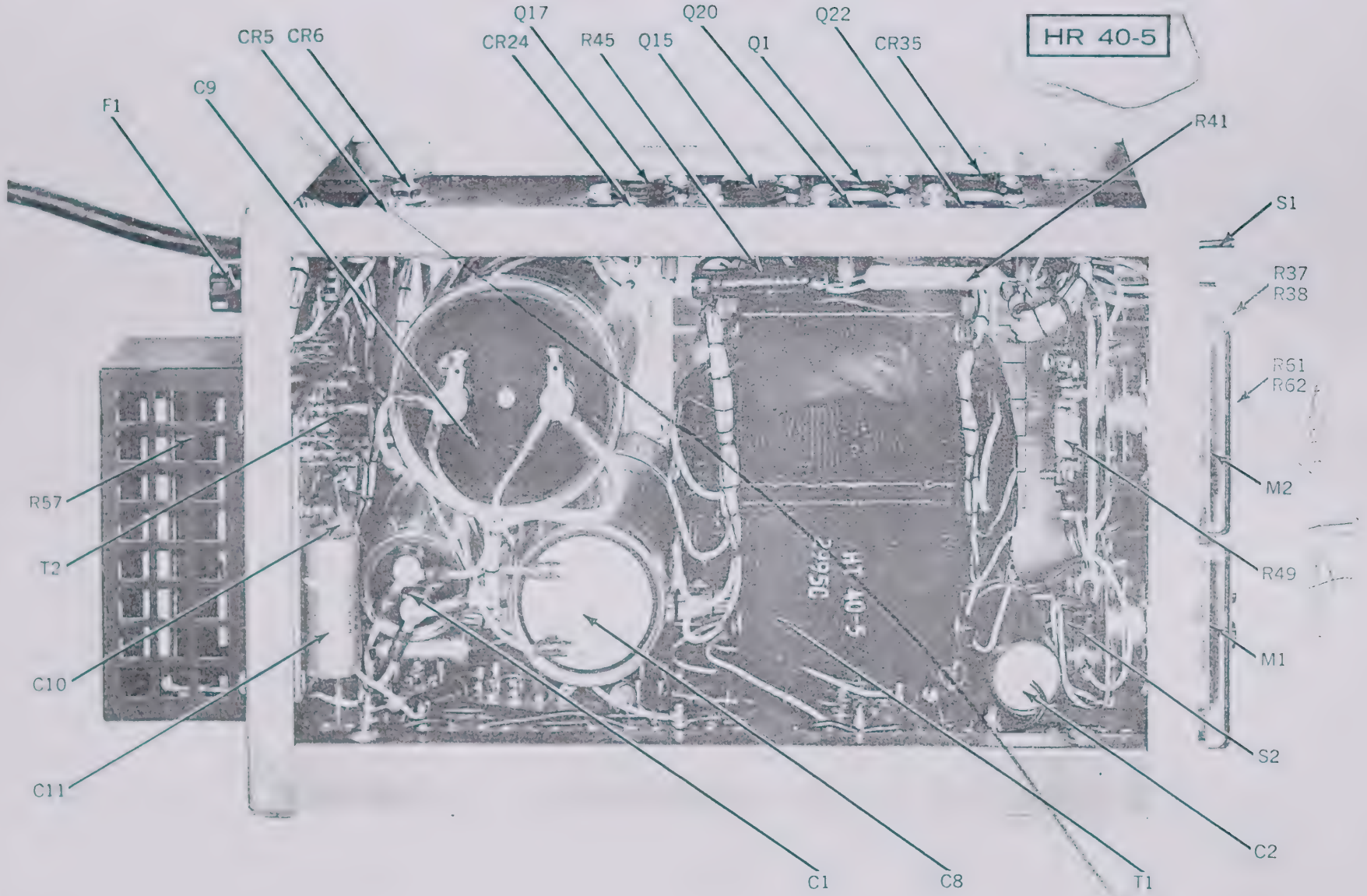
A) Connect a test ammeter having a full scale current indicating capacity of 150% that of the rated current output across the output terminals of the power supply. (Set all front panel controls fully CCW.) Apply power to the unit under test and slowly rotate CURRENT ADJUST control R62 and CURRENT VERNIER

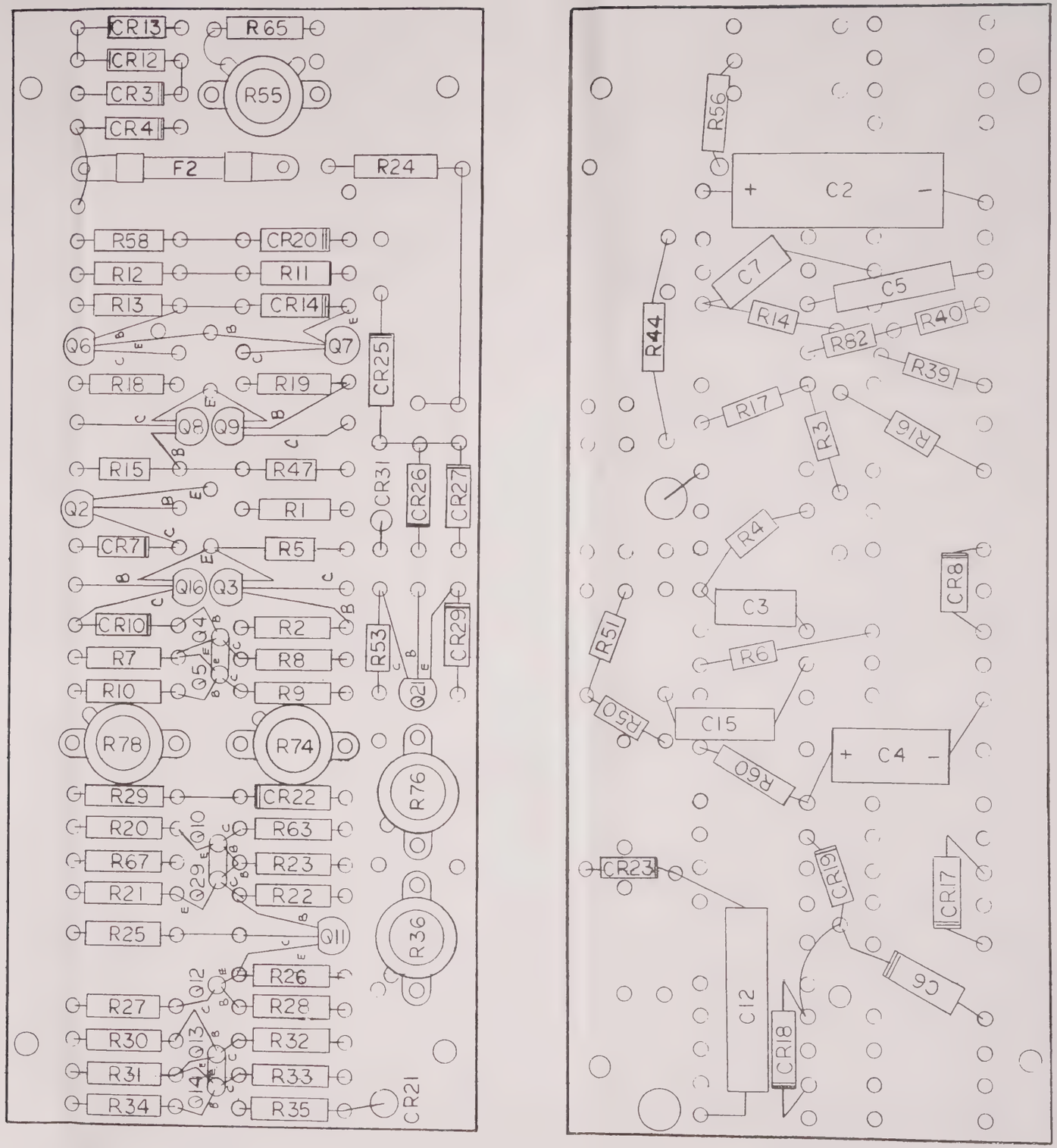
5.3.5 Maximum Current (Continued)

control R61 fully CW. Observe that the maximum current obtainable is approximately 120% that of the rated current output. If it is not possible to achieve 120% of the rated current output, adjust Maximum Current control R78 until that value is attained. Set AC Power Switch to OFF.

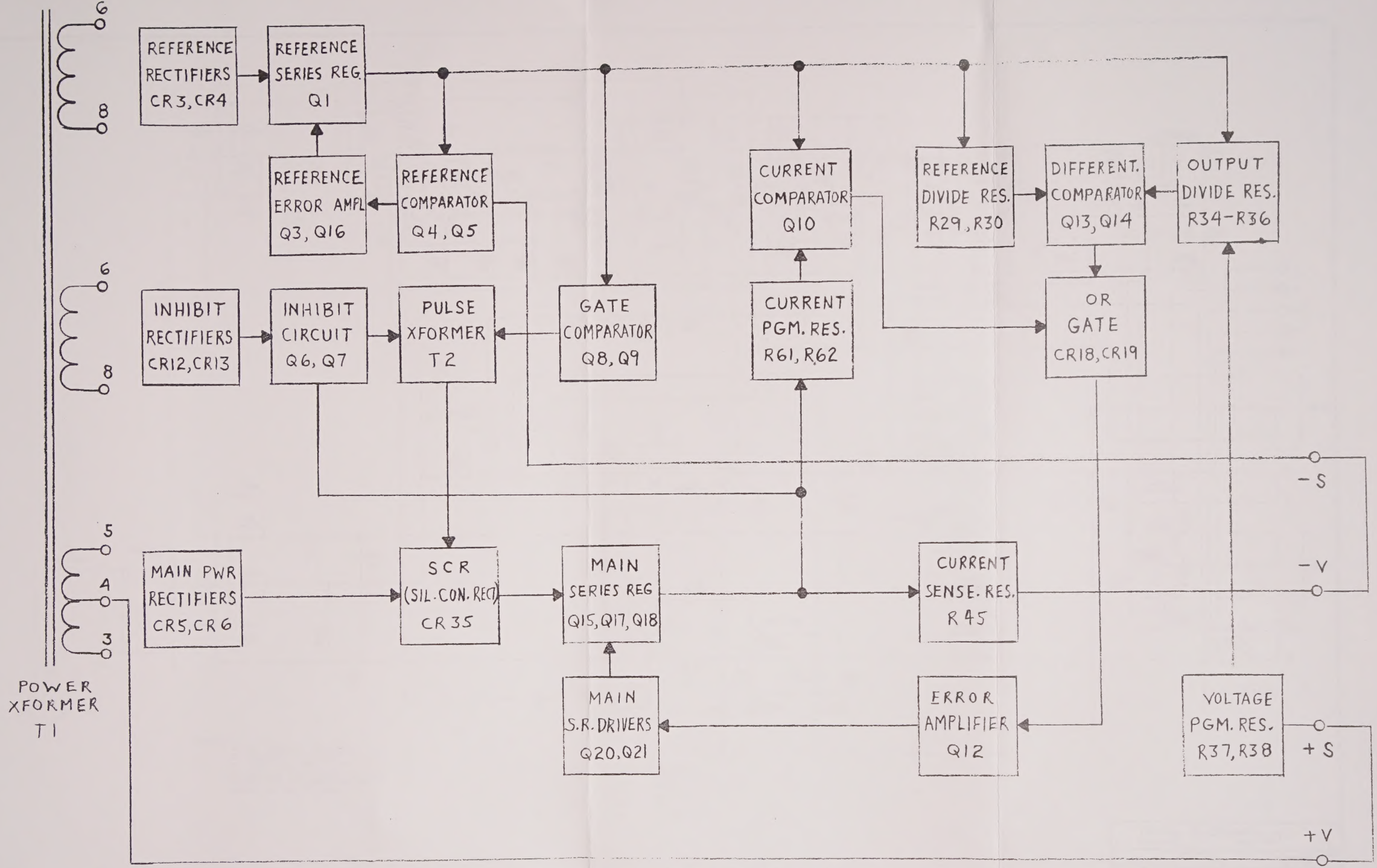
B) Connect a suitable load resistance across the output terminal connections. The load resistance must be able to dissipate the rated power of the unit (P = IE) and must be of sufficient value to yield the rated output current when the rated voltage is applied. Set AC Power Switch to ON. Note the voltage indicated on the Differential VTVM. Disconnect the resistive load from the output and observe the voltage indicated on the Differential VTVM. The maximum change in output voltage should not exceed by more than 0.01% or 3mv (whichever is greater) that of the output voltage indicated with the load resistance applied across the output terminals.

C) If it is not possible to maintain the load regulation as stated in the preceding paragraph, re-adjust Maximum Current control R78 slightly and re-check the load regulation. Further minor adjustment of Maximum Current control R78 may be necessary to achieve both proper load regulation and 120% of rated current output.


HR 40-5
Q17
CR24
R45
Q15
Q20
Q1
Q22
CR35
CR5
CR6
C9
F1
R41
S1
R37
R38
R51
R62
M2
R49
M1
S2
C2
R57
T2
C10
C11
C1
C8
T1
2495C
HR 40-5

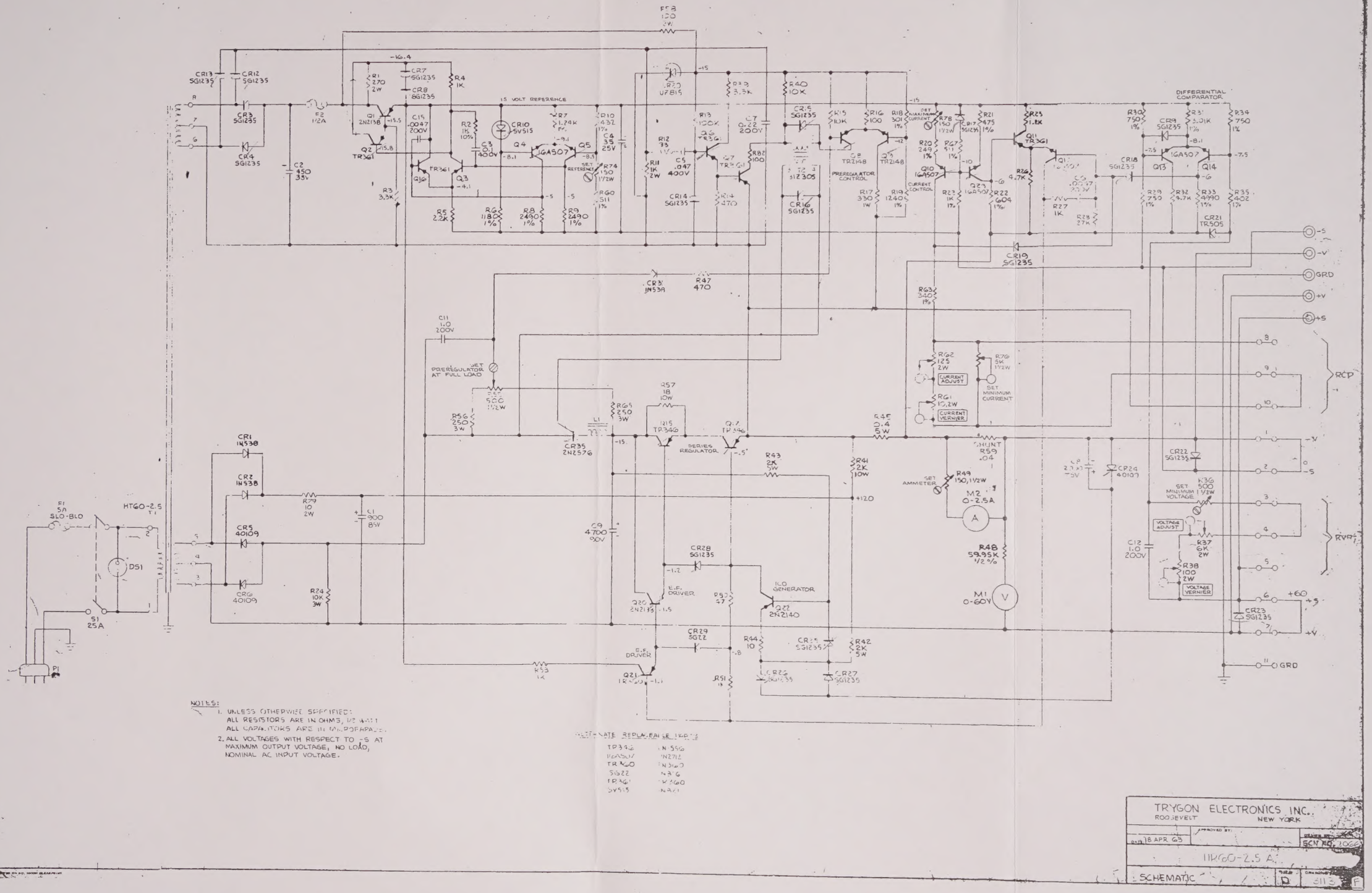


COMPONENT BOARD



BLOCK DIAGRAM

MEDIUM POWER HALF RACK



NOTES:

1. UNLESS OTHERWISE SPECIFIED:
   ALL RESISTORS ARE IN OHMS, 1/2 WATT
   ALL CAPACITORS ARE IN MICROFARADS.
2. ALL VOLTAGES WITH RESPECT TO -S AT MAXIMUM OUTPUT VOLTAGE, NO LOAD, NOMINAL AC INPUT VOLTAGE.

ALTERNATE REPLACEABLE TYPES

TP346	2N5960
IGA507	2N2712
TR3G0	2N5160
SG1235	1N2976
TR3G1	2N5160
5V515	1N821

TRYGON ELECTRONICS INC.
ROOSEVELT NEW YORK

DATE 18 APR 63	APPROVED BY:	DRAWING NO. SCH NO. 1060
11K60-2.5 A		
SCHEMATIC	SIZE D	SHEET 1 OF 1